Do-It-Yourself Diodes

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Ed Nisley - KE4ZNU
ed.nisley@ieee.org
Coming Attractions

Radio Rocks
EZ Curve Tracer
Radio Circuit Model
Mineral Diodes & Thingies
Rust Never Sleeps
Why Diodes Matter
In The Beginning

- Before integrated circuits...
- Before transistors...
- Before vacuum tubes...
- Before electronics...
- ... there were radios!
  - Modern radio by VE6AB
The Simplest Possible Radio

- Antenna
- Ground
- Earphone
- Detector
  - AM demodulator (huh?)
  - A rock on a hard place
  - Crystal diode!
- Tuning? Hah!
Mineral Samples

- Who knew?
  - Nobody!
  - Conflicting stories

- Try all combinations
  - Most don’t work at all
  - How can you tell?

- Instrumentation!
The Big Idea

- Jam current (I) in
  - How much?
  - Polarity?
- Measure volts (V) across
  - Range?
- Plot results: curves!
  - It can be done manually
  - More fun automatically
  - Oscilloscope screen shots
The Little Details

- Triangle wave input
  - 200 Hz, 8 V peak
  - Voltage to Current
  - Oscilloscope X axis
- Measure V at sample
  - Differential to single
  - Oscilloscope Y axis
  - ±10 mA and ±10 V
- Still makes sparks…
Enlarged to Show Texture

Op Amp must supply up to 10 mA output

Use SIP resistor pack to match R4-R7

Sample Probe

Voltage across sample

Current through sample 1 V = 1 mA

Bipolar input 1V = 1 mA

1k

TRIANGLE R3

1k
Cat’s Whisker Probe

- Mineral in metal pot
- Wire pin-point probe
  - Steel? Bronze? Carbon?
- 3-axis ball slide mount
- Springy thing
- Patience
He Who Dies With The Most Stuff…

- 3-axis positioner
  - 0.001” resolution
  - 0.5” accessible cube
  - Zero backlash

Black-belt dweebdom
Probe and Sample Holder

- Telescoping brass tubes
- Tapered clock pins
- Springy thing
- EMT fitting
- Gratuitous CNC
- Low frequency = clips
Sample Holder

- **Wood’s Metal**
  - Makes solid contact
  - But: $\text{Pb+Cd+Bi+Sn}$
  - But: melts at 160° F
  - Use Field’s Metal?
- **Friction-fit probe tips**
  - Steel, bronze, carbon
  - Small differences?
Calibration – 1 kΩ Resistor

- 1 V input = 1 mA
- Scope Axes
  - X = current (2 mA/div)
  - Y = voltage (2 V/div)
- Linear!
  - Whew…
- Set DC offset = 0
Calibration – 1N914

- Jellybean Si diode
  - \( V_{\text{fwd}} = 0.5 \text{ V} \)
    - Pretty close
  - \( I_{\text{rev}} = \text{zilch} \)
    - Limited by diff amp’s input resistance
Iron Pyrite

- Green trace
  - Nearly a resistor
- Red trace
  - More like a diode
- Blue trace
  - Both better & worse
- Same lump!
- Probe material?
Spice Circuit Model

- Diode = switch
  - Voltage controlled
  - Maybe a lousy switch
- Resistance from plots
  - \( R = \frac{\Delta V}{\Delta I} = \text{slope} \)
- \( C1 \) & \( R2 \approx \text{earphone} \)
  - High impedance
- \( V1 \times V2 = \text{AM signal!} \)
AM Demodulation

- Low voltage RF
  - This is before tubes!
- Poor diodes are OK
  - Green $\approx 3.6 / 1$ (rev/fwd)
  - Red $\approx 5.6 / 1$
- Modern diodes are NG
  - Purple = Schottky $\approx \infty / 1$
  - But $V_{\text{fwd}}$ still too high
Iron Pyrite

- Huh?
  - Sorta Zener-ish
- Marginal diode
  - For low I & V, anyway
Lead - Galena?

- Backwards polarity
  - Whatever that means
- Low $V_{\text{fwd}}$
- Bronze probe
- Best of a bad sample
  - Who knew?
  - Maybe it’s just lead?
Chalcopyrite

- Say kal’•keh•pie’•right
- Looks diode-ish
  - If you squint
- Low $V_{fwd}$
- But wait...
Chalcopyrite

- It’s a Diac!
  - Bilateral trigger diode
- It’s a resistor!
  - For very low I
- Negative resistance
  - Current $\uparrow$ = Voltage $\downarrow$
- Note scale change
  - 5 V and 5 mA / div

![Graph showing the Diac behavior with scale change]
Galvanized Steel

- Propane torch
  - Little black spots…
  - Do this outdoors!
- Iron-tin-zinc alloy?
  - Cadmium? Ick!
- Looks like high R
  - And not a diode
- But wait…
Galvanized Steel Bestiary
Rust Never Sleeps

- Ordinary steel bolt
- Salt + towel + copper
  - Cu + Fe = 650 mV
  - At *only* 1 mA
  - Slow and steady
- AA cell
  - 1500 mV & 10 mA
  - 4 hours later…
Steel Corrosion

- Nonlinear
- Symmetric
  - Sorta, kinda
- Negative resistance
- Oscillator!
- No Battery Needed
  - Self-biasing circuitry
  - DC bias + small AC
Linear Mixing Circuit

- Linear mixing
  - Only “resistors”
  - Sum of amplitudes
  - No surprises
  - Ohm’s Law, etc
Linear Mixing Results

$F_1 = 500 \text{ Hz}$

$F_2 = 700 \text{ Hz}$

$2xF_2 = 1400 \text{ Hz}$
Nonlinear Mixing Circuit

Nonlinear mixing

- Usually a diode, but …
- Any nonlinearity will do
- $\pm nF_1 \pm mF_2$
- Amplitudes? Hah!
- No analytic equations
- Simulation values?
Nonlinear Mixing Result

\[\pm nF1 \pm mF2\]
RF vs. The Rusty Bolt

- Mountaintop radio
  - *Many* transmitters
  - High RF field intensity
  - Sensitive receivers
  - Galvanized towers
  - Acid rain
- Corrosion
- Intermodulation!
  \[ \pm nF_1 \pm mF_2 \pm pF_3 \pm \ldots \]
DIY Diodes

- They’re everywhere
- They’re cheap
  - OK, not that positioner
- They’re easy, sorta
- You’ll learn…
  - … about electronics
  - … about patience

Demo: Sunday AM!!
References

My column in Circuit Cellar magazine: www.circuitcellar.com
    October 2006 is mostly this talk, has file of scripts, pictures, other stuff
    February & April 2003 describe nonlinear frequency mixing

Semiconductor curve tracer using PC sound card: George Steber, WB9LVI
    Circuit Cellar, Jan 2004

Good overview of crystal-set parameters: http://www.oldradioworld.de/gollum/analysis.htm

Zinc negative resistance oscillators: http://home.earthlink.net/~lenyr/zincosc.htm

Galvanic Series table: http://www.ocean.udel.edu/seagrant/publications/corrosion.html

Wood’s metal, springs, phosphor bronze sheet, tools from MicroMark: http://micromark.com/

Taper pins and small parts from S. LaRose, Inc: http://www.slarose.com/ (dead on 18 Aug 06)

Capturing oscilloscope traces with Kermit: http://www.columbia.edu/kermit/index.html

Converting HPGL to bitmaps with hp2xx utility: http://www.gnu.org/software/hp2xx/
Who Am I?

Ed Nisley

- Say “NISS-lee”, even though my ancestors were half-essed
- Engineer, author, tinker, family guy
- Circuit Cellar: Above the Ground Plane - [www.circuitcellar.com](http://www.circuitcellar.com)
  - Analog & RF stuff
- Dr Dobb’s Journal: Nisley’s Notebook - [www.ddj.com](http://www.ddj.com)
  - Embedded systems & hardware stuff